

## A trapped $^{171}\text{Yb}^+$ ion optical frequency standard based on the $S_{1/2} - F_{7/2}$ transition

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The single cold  $^{171}\text{Yb}^+$  ion has two optical clock transitions which have been the subject of recent studies. One of these, the  $^2S_{1/2} - ^2D_{3/2}$  quadrupole (E2) transition at 436 nm has been investigated extensively at PTB [1]. The other is the  $^2S_{1/2} - ^2F_{7/2}$  octupole (E3) transition at 467 nm, which has an extremely narrow theoretical linewidth on account of the 6-year lifetime of its  $F_{7/2}$  upper level [2]. Experimentally, the observable cold ion linewidth is that dictated by the laser linewidth and probe time characteristics. Laser linewidths of  $\sim 5$  Hz over few-second timescales have been achieved at the 934 nm fundamental wavelength for a Ti:sapphire probe laser stabilised to an ultra-low-expansion (ULE) reference cavity [3], broadening to 20 Hz on the timescale of 1 minute. This longer timescale typically represents the interval needed to scan the second harmonic of the probe laser over the cold ion octupole linewidth. Under these conditions, cold ion octupole linewidths at the doubled frequency of less than 40 Hz have been observed [4].

Recent absolute frequency measurements of the octupole transition line-centre with a Ti:sapphire femtosecond comb have led to a frequency uncertainty of 12 Hz ( $1\sigma$ ) [4]. This result has been achieved by scanning over the transition at several different probe laser power levels, allowing extrapolation to zero intensity and estimation of the ac Stark shift. Research is currently underway to reduce the ULE cavity sensitivity to vibrations and apply a servo-locking algorithm, which should give a further reduced uncertainty.

Two separate  $\text{Yb}^+$  trap systems have been developed in anticipation of comparison studies to characterise the level of systematic frequency shifts and uncertainties for the octupole transition. Already, the ac Stark shift and second order Zeeman shift coefficients have been characterised [5], and operational conditions identified where these shifts are not the dominant perturbations. The octupole transition also has a very small quadrupole shift, and with adequate control of the blackbody shift through temperature characterisation of the trap environment, this should enable uncertainties below  $10^{-17}$  to be achieved.

The frequency ratio between the  $^{171}\text{Yb}^+$  quadrupole and octupole transitions is of particular interest as it demonstrates one of the largest sensitivities for monitoring possible time variation of the fine structure constant. To this end, we are developing a 436 nm probe laser for probing the 436 nm quadrupole transition in conjunction with the octupole transition. Progress in these areas will be reported at the Symposium.

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[2] M Roberts et al., Phys. Rev. A **62**, 020501(R) (2000)

[3] S A Webster, A Stannard, K Hosaka and P Gill, Proc. 21<sup>st</sup> EFTF (2006)

[4] K Hosaka et al., 2008 (manuscript in preparation)

[5] K Hosaka et al., IEEE Trans. Instrum. Meas. **54** 759-762 (2005)